



Southwest  
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# ***CLEANER MARINE ENGINES - CAN IT BE DONE?***

Presentation to ***Carbon Monoxide Workshop***

by

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# Background

## What's Going On?

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Both EPA and CARB are developing emission regulations to cover sterndrive and inboard (SD/I) SI marine engines

CARB SD/I rule adopted at Board hearing on July 26, 2001

- standards supported by marine industry

July 25, 2002 EPA NPRM proposes evaporative standards for SI marine engines

- Not planning exhaust emission standards until more information available about catalyst application in the marine environment

# What Technologies Can Potentially Be Applied to SD/I Engines?

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Electronic fuel injection (EFI)

Stoichiometric or low-emissions calibrations

- requires exhaust gas oxygen (EGO) sensor

Exhaust gas recirculation (EGR)

- reduces NO<sub>x</sub> emissions

Aftertreatment - catalysts

- reduce HC, CO, and NO<sub>x</sub>

# Marine Engine Catalyst Application Issues

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## Safety - Under-Deck Temperatures

- Potential for catalyst to overheat
- Spec. is 200 F max. surface temperature
- Can this be adequately protected against?

## Safety - Exhaust Leaks

- Additional connections and components provide additional opportunities for leaks

## Durability - Can ceramic components survive marine environment?

- Water can quickly destroy hot ceramic components

## *Potential Safety Benefit*

- Reduction or elimination of CO danger behind boats

# What's Been Done So Far?

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SwRI has performed two projects for CARB and EPA to demonstrate the potential for cleaner SD/I engines  
“Catalytic Reduction of Marine Sterndrive Engine Emissions”

- Applied EGR and catalyst to marine V-8 engine
- Determined effects on engine performance and emissions
- Identified 2 systems capable of reducing HC+NOx emissions by 80%

“Marine Exhaust System Modifications”

- Investigated water reversion problem
- Proposed several modifications to exhaust system design
- Tested modified systems in a boat on a lake
- Virtually eliminated reversion using heated manifold concept

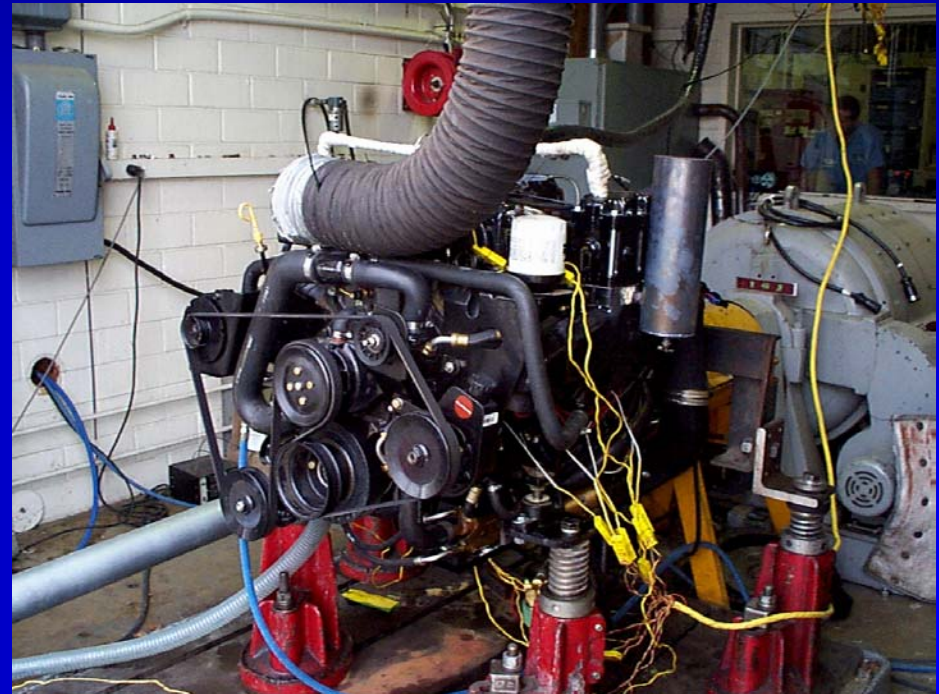
# SwRI SD/I Research Project

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Objective: Determine level of emission reduction achievable on typical SD/I engine

Approach: Apply EGR and catalyst technology to Mercury Marine 7.4L V-8

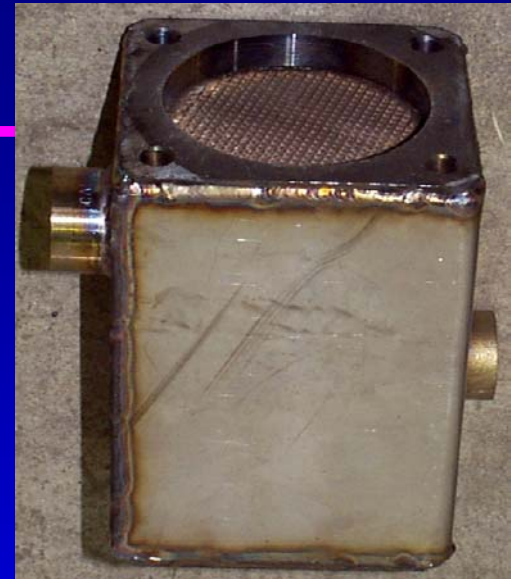
- install in test cell
- take performance and emissions data



# Best Configurations

## Riser Catalysts

- expanded exhaust passage to reduce back pressure with same external dimensions as stock Mercury riser
- 80% reduction in HC+NOx
- 50% reduction in CO



## Expanded Elbow Catalyst

- allows catalyst use without increasing height or width
- designed to prevent water reversion
- 75% reduction in HC+NOx
- 50% reduction in CO



# **“Marine Exhaust System Modifications”**

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Project performed by SwRI for CARB

Objective:

- investigate water reversion problem and propose possible solutions

Approach:

- study marine engine water reversion in boat on a lake using industry-specified test procedures
- formulate modifications to exhaust system design
- apply modifications in boat and test to determine effectiveness

# On-Lake Testing

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Instrumented 4.3 L V-6 in Sea Ray 190 boat  
Performed on-water testing to study water reversion

- NMMA Recommended Test Modes
- SwRI Added Test Modes

Accumulated water seemed to be caused more by condensation than reversion

Developed exhaust system modifications to reduce exhaust system condensation

Modifications effective in protecting catalyst and oxygen sensor

# **“Development of Low Emissions SD/I Boats” SwRI Project for CARB**

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## Objectives:

- Develop catalytic marine exhaust systems
- Demonstrate durability of these systems in boats on the water

## Primary Tasks:

- Develop stoichiometric marine engine calibrations
- Design and fabricate 4 catalytic marine exhaust systems
- Install systems in 4 boats
- Perform on-water durability
- Evaluate performance and durability of the emission reduction systems

# Current Project Status

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Project started ~ mid-August

Boats shipped to SwRI

Catalysts designed and shipped by MECA member companies

Catalyzed exhaust manifolds being fabricated

Communication with Coast Guard Auxiliary

Emissions calibration work ongoing

Procuring instrumentation for on-water activities

# ***Durability of Low-Emissions Small Off-Road Engines***

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## *Project Background*

CARB planning further reductions in emission standards for small off-road engines (SORE)

Catalyst technology could be required to meet future standards

Questions remain about the durability of catalysts applied to small off-road engines

# Objective

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Demonstrate durability of catalyst application to small off-road engines

- Emissions target is 50% of engine 0-hour baseline HC+NOx emissions at either 250 hours (Class 1 engines) or 500 hours (Class 2 engines)

# Development of Low-Emissions Engines

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Perform baseline, 6-mode emission tests, as received  
Install catalysts and develop low-emissions calibrations

- Adjust A/F calibrations, as required
- Consider use of supplemental air

Emission test developed engines

- obtain pre- and post-catalyst data

Install evaporative emission control technologies on two engines

- Low-permeability fuel tank and line
- Measure evaporative emissions in baseline and low-evaporative configurations

# Durability Testing

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Durability to be performed using repetitive 6-mode cycles (Cal. Phase II RFG)

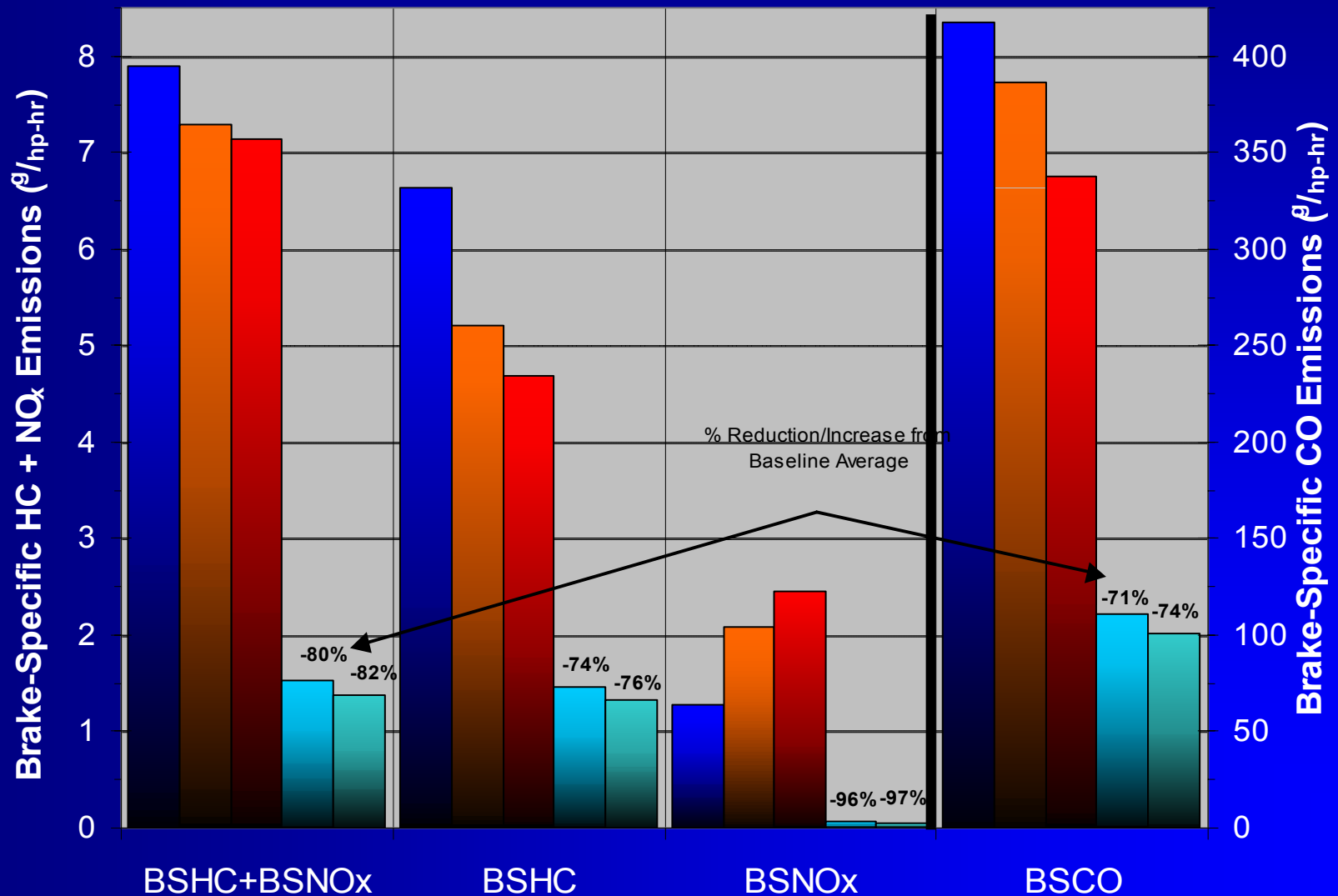
Class 1 engines:

- 250 hours total
- Emission tests at 125 and 250 hours

Class 2 engines:

- 500 hours total
- Emission test at 125, 250, and 500 hours

# Small Offroad Engine #1



# Current Approaches To CO Reduction

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## Lean Engine Operation

- LPG Fuel
  - Lift trucks, floor waxers, Zamboni
- Diesel Fuel
  - Gen sets, marine propulsion

## Closed -Loop Control

- Stoichiometric operation with catalysts
- Large spark-ignited engines (>25hp)
- Gen sets, lift trucks, airport ground support, man lifts, pumps

## Development of Four-Stroke Outboard Engines

# Challenges

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## Small Offroad Engines (<25hp)

- Engine thermal durability, catalyst durability, costs of catalytic mufflers

## Large Spark-Ignited Engines (>25hp)

- Commercially available

## Marine Propulsion Engines

- Packaging catalyzed exhaust
- Durability of catalyst and EGO sensor
- Development of closed-loop control calibrations

# Questions?

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